

Figs. 7 and 8 represent these values of  $x$ ,  $n$ , and  $m$ , respectively, the curves marked 1 being those obtained with tin at  $650^{\circ}$ ; those marked 2 with tin at  $800^{\circ}$ ; and those marked 3 with silver at  $800^{\circ}$ ; the value of  $x$  being abscissæ, and those of  $m$  and  $n$  ordinates.

We have much pleasure in acknowledging the assistance afforded us by Mr. T. M. Wyatt in carrying out a considerable portion of the analytical results above detailed.

II. "Experiments on Vapour-density." By E. P. PERMAN, B.Sc., Clothworkers' Exhibitioner at University College, London. Communicated by Professor RAMSAY, F.R.S. Received April 17, 1890.

*The Vapour-density of Bromine.*

The main purpose of my work on this subject was to discover if bromine had any tendency to dissociate at low pressures, *i.e.*, down to about 15 mm. of mercury, and at moderate temperatures.

The subject was suggested by Professor Ramsay, to whom I am greatly indebted for constant advice and assistance in carrying out the work. The method adopted for determining the vapour-densities was a modification of the Dumas method, from which it differed in three essential points:—(1) The globe was not immersed in a bath, but had a vapour-jacket. (2) The weight of the vapour in the globe was not found by direct weighing, but by running in an absorbent liquid, and estimating it volumetrically. (3) A series of vapour-density determinations at different pressures was made with the same quantity of vapour by lowering the pressure, absorbing the vapour drawn off and estimating its quantity.

As to previous work on this subject, Jahn has shown ('Wien, Akad. Sitzber.,' vol. 85, 2. Abth., 1882, p. 778) that the vapour-density becomes normal at about  $230^{\circ}$ ; Meier and Züblin ('Deutsch. Chem. Ges. Berichte,' vol. 13, 1880, p. 405) and Crafts ('Comptes Rendus,' vol. 90, 1880, p. 183) have shown that partial dissociation takes place at very high temperatures; and Professor J. J. Thomson states that "vapour-density determinations showed that bromine vapour is dissociated if it is heated for a long time at a low pressure, even though the temperature is not very high" ('Roy. Soc. Proc.,' vol. 42, 1887, p. 345). His chief results are:—

Pressure.	Temperature.	Density.	Remarks.
mm.	°		
543	89	81.7	In bath 24 hours.
235	109	77.0	Sparked.
230	100	66.5	In bath 4 hours.
165	90	77.0	Only short time in bath.
390	111	70.0	In bath 7 hours.

These results were so abnormal that it was deemed necessary to make fresh experiments.

*Description of Apparatus.*—The apparatus used consisted of a glass globe, A (fig. 1), of about half a litre capacity, blown inside of a larger

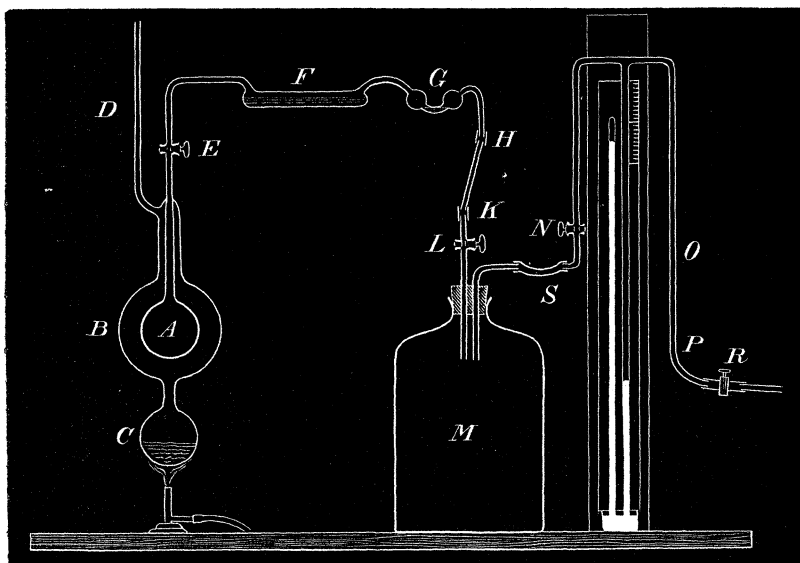


FIG. 1.—Apparatus used for determining the Vapour-density of Bromine.  
(Section.)

globe, B. The liquid which produced the vapour-jacket was boiled in a small globe, C, connected with the outside globe B, and condensed in the tube D, round which, when necessary, a condenser was fixed. Further to the right came an absorption-tube, F, with a small bulb-tube, G, containing a few drops of the same liquid as was introduced into the absorption-tube, viz., potash solution during the boiling-out process, and afterwards a strong solution of potassium

iodide; then came an air-reservoir, M, and a pressure-gauge, O, arranged as shown in the diagram. There were stopcocks at E, L, and N; rubber joints at H, K, and S; and a screw-clip at R on the tube P, leading to a water-pump.

*Method of Procedure.*—The capacity of the globe A was accurately determined by weighing the apparatus empty, and then full of water; it was filled from a wash-bottle, which was also weighed as a check on the other result.

Pure bromine was specially prepared by boiling commercial bromine with potassium bromide for a day, distilling it through a tube containing red-hot manganese dioxide, and redistilling with phosphoric anhydride; after a small portion had distilled over, the boiling point was constant at  $59^{\circ}09$  (reduced to 760 mm.). Asbestos plugs were found very useful in working with bromine; by their use a good joint can be secured if *liquid* bromine is not allowed to come into contact with the asbestos. The thermometer in the distilling-flask was secured by a plug of asbestos, and its bulb was surrounded with asbestos to prevent superheating.

To commence an experiment, the globe was rinsed with ether, and dried by repeated exhaustion and admission of air; some bromine was run in without admitting air, the tube above E was fused on to the absorption-tube, F, by means of a portable blowpipe, the liquid in C was boiled, the stopcock E cautiously turned till the pressure within the globe was equal to the atmospheric pressure, and then opened from time to time till the bromine ceased to blow out. All the bromine was absorbed in F, which at this stage contained potash solution. The stopcock E and the tube above and below it were gently heated by means of a Bunsen's burner. The absorption-tube was then connected with the reservoir M, and the air was partially exhausted from the whole apparatus; to complete the exhaustion as far as possible, the globe and the absorption-tube were directly connected with the pump. The stopcock E was then turned off, the tube above it was cracked and removed, more bromine was admitted, the tube fused together again, and the bromine driven out as before till the pressure in A was equal to the atmospheric pressure. The globe was then full of bromine vapour at the atmospheric pressure, and at the temperature of the jacketing vapour, and was ready for a vapour-density determination, or for a series of determinations. The absorption-tube was rinsed out, and partly filled with a strong solution of potassium iodide; it was then clamped in its place, and connected with the globe A, and with the reservoir M. The water-pump was then set to work till the reservoir was exhausted sufficiently—the degree of exhaustion depending upon the number of vapour-density determinations which were to be made in the series. The pump was then cut off by the screw-clip R, and

he stopcock E turned very cautiously, letting out the bromine vapour little by little; when it ceased to come over, the globe and its contents were left for two or three minutes in order to regain the heat lost by the adiabatic expansion; it was necessary to repeat this process till the bubble in the bulb-tube G remained undisturbed on quickly opening and closing the stopcock E. The pressure recorded by the gauge was then carefully read, the stopcock L was closed, the absorption-tube removed, and its contents washed into a stoppered bottle. The whole process was repeated at successively lower pressures till the lowest desired was reached; a good water-pump will reduce the pressure to the vapour-pressure of water at the temperature of the water passing through the pump.

The residual bromine in the globe was estimated by running in potassium iodide solution, and titrating with a standard solution of sodium thiosulphate. The successive quantities of bromine collected in the absorption-tube were also estimated in the same way. The thiosulphate solution was standardised with the specially prepared bromine, and also with pure iodine; the results agreed within 0·2 per cent., and the mean value was used.

By adding together the residual quantity of bromine and the quantities removed, the weight of bromine in the globe at each pressure was found. The capacity of the globe being accurately known, and also the temperature of the jacket from the tables of Professors Ramsay and Young ('Chem. Soc. Journ.,' vol. 47, 1885, p. 640), the data requisite for the determination of a series of vapour-densities at different pressures were available.

*Results.*—After some practice in conducting the experiment, satisfactory results were obtained; they are tabulated below:—

Series I.—Temperature, 77°·8 (Alcohol); Capacity of Globe, 446·3 c.c.

	Weight of bromine.	Pressure.	V.-d.
	grms.	mm.	
1.	2·410	744·9	79·2
2.	1·856	575·9	78·9
3.	1·383	431·2	78·5
4.	1·146	355·9	78·8
5.	0·6732	208·4	79·1
6.	0·3388	103·6	80·1
7.	0·1144	33·9	82·6

Some bromine escaped absorption, causing the first vapour-densities to be too low.

## Series II.—Temperature, 78°·4.

	Weight of bromine.	Pressure.	V.-d.
	grms.	mm.	
1.	2·640	764·3	81·0
2.	1·552	452·0	80·5
3.	0·4848	141·4	80·4
4.	0·05933	15·45	90·1

The only noticeable point in this series is the highness of the last vapour-density at the lowest pressure.

A single experiment was then made in order to try the effect of continued heating on bromine vapour at a low pressure. After three hours' heating at 78°·0 and 15·35 mm. pressure, the vapour-density came out abnormally high, viz., 92·6. Professor J. J. Thomson found vapour-densities 66·5 and 70 at much higher pressures and somewhat higher temperatures than these.

## Series III.—Temperature, 155°·5 (Bromobenzene); Capacity of Globe, 447·1 c.c.

	Weight of bromine.	Pressure.	V.-d.
	grms.	mm.	
1.	2·114	749·0	80·8
2.	1·192	423·9	80·3
3.	0·3309	117·4	80·7
4.	0·09833	34·9	80·4

Here there is still no sign of dissociation, and what seems somewhat remarkable, even at low pressures the vapour-density is above the normal density.

The pure bromine being then exhausted, a fresh sample was prepared from the residues and from some commercial bromine treated with potash; the whole was evaporated to dryness, ignited, distilled with sulphuric acid and potassium bichromate, and dried by shaking with sulphuric acid, allowing to stand, and re-distilling; the greater portion came over at 58°·9 (corrected to 760 mm.), it commenced to boil at 58°·55, but the boiling point soon rose to 58°·9, and then remained constant.

A determination was then made of the density of bromine vapour as nearly as possible saturated at 15°. The globe was immersed in

a pan of water, and the pressure was made so near the saturation-pressure that the bromine took three hours to vaporise completely.

Series IV.—Temperature,  $14^{\circ}7$ — $15^{\circ}$ ; Capacity of Globe, 445.6 c.c.

	Weight of bromine.	Pressure.	V.-d.
	grms.	mm.	
1.	0.4125	98.65	80.3
2.	0.2661	63.70	80.4
3.	0.1355	32.10	81.3
4.	0.07205	16.65	83.3

The vapour-pressure of bromine at  $15^{\circ}$  is 138.1 mm., according to the tables of Professors Ramsay and Young ('Chem. Soc. Journ.,' vol. 49, 1886, p. 445). These results show that, on approaching the liquid state, bromine has no tendency to form molecules with more than 2 atoms. This agrees with the results of Paternò and Nasini ('Deutsch. Chem. Ges. Ber.,' vol. 21, 1888, p. 2153) by Raoult's method, which indicated molecules  $\text{Br}_2$  in aqueous and acetic acid solutions.

Series V.—Temperature,  $279^{\circ}5$  (Bromonaphthalene); Capacity of Globe, 448.6 c.c.

	Weight of bromine.	Pressure.	V.-d.
	grms.	mm.	
1.	1.625	744.7	80.0
2.	0.5072	233.2	79.8
3.	0.2138	98.1	80.0
4.	0.1082	49.45	80.3
5.	0.04939	21.85	82.9

The temperature employed in this series was much higher than the temperatures used by Professor J. J. Thomson in his experiments; some of the pressures were much lower, and the total time of heating was about five hours, yet there was no sign whatever of any dissociation.

Finally, an experiment was made with bromine in presence of air. The bromine was boiled out of the globe at exactly half the atmospheric pressure, and air was then slowly admitted until the pressure inside and out was the same.

Series VI.—Temperature, 132°·2 (Chlorobenzene); Capacity of Globe, 509·2 c.c.; Volume occupied by Bromine Vapour, 254·6 c.c.

	Weight of bromine.	Pressure.	V.-d.
	grms.	mm.	
1.	1·234	761·4	80·3
2.	0·6379	392·3	80·5
3.	0·1953	120·0	80·6
4.	0·08763	53·8	80·7
5.	0·03972	23·0	85·5

The results are negative, as before, but no doubt dissociation would be produced if the temperature were carried high enough, and I hope to carry on my experiments with a modified form of apparatus until dissociation takes place. I must ask my fellow-workers to kindly leave to me the completion of this work.

*Remarks.*—One of the most striking features in the series of vapour-densities is the invariable increase in density at low pressures; this may be accounted for partly by the error unavoidable in reading low pressures, and partly by the irregularity in the position of the liquid in the bulb-tube G; but these errors together would never amount to more than 1 mm. of mercury, seldom so much. As the chief cause of the anomaly, I would suggest that a film of bromine may adhere to the glass, and thus cause the residual amount of bromine to be too large.

#### *Vapour-density of Iodine.*

*Previous Work.*—V. Meyer obtained vapour-densities closely corresponding to a molecule  $\frac{2}{3}\text{I}_2$ , at a temperature which he estimated at 1570° ('Deutsch. Chem. Ges. Ber.' vol. 13, 1880, p. 394).

Crafts and Meier found a greater amount of dissociation than V. Meyer at about the same temperature, which, however, they estimated at 1390° instead of 1570°; the lowest vapour-density they obtained was 75·6 ('Comptes Rendus,' vol. 90, 1880, p. 690).

Deville and Troost found the vapour-density normal at 860° and 1034° ('Annales de Chimie,' vol. 58, 1860, p. 257). Crafts and Meier, in further experiments, obtained complete dissociation of iodine vapour, and they give a curve showing the amount of dissociation at different pressures and temperatures ('Comptes Rendus,' vol. 92, 1881, p. 39). Crafts obtained partial dissociation by a modification of V. Meyer's method ('Comptes Rendus,' vol. 90, 1880, p. 183). Troost obtained a very considerable amount of dissociation by the Dumas method at 1250°; the lowest number obtained was 81·6; he also found the

vapour-density at  $440^{\circ}$  and 34.5 mm. pressure to be 106.2 ('Comptes Rendus,' vol. 91, 1880, p. 54). The dissociation of iodine has thus been worked out with fair completeness, although the results of

FIG. 2.

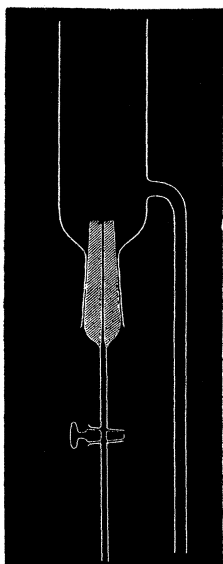
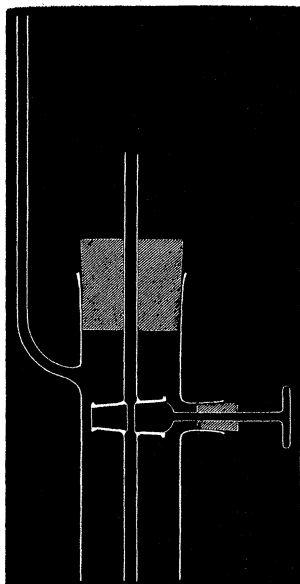


FIG. 3.



Forms of Apparatus used for Iodine and Aqueous Hydrochloric Acid. (Section.)

Deville and Troost seem very much at variance with those of other experimenters. The object of my work was to discover the density of iodine vapour as nearly as possible saturated. A modified form of apparatus was devised by Professor Ramsay so that the iodine could be conveniently introduced into the globe. The modification consisted of the introduction of a stopper at the neck of the globe with a capillary tube through the centre. The method of procedure was the same as with bromine, except that it was necessary to heat the

Temperature,  $131^{\circ}4$  (Chlorobenzene); Capacity of Globe, 517.6 c.c.

	Weight of iodine.	Pressure.	V.-d.
	grms.	mm.	
1.	0.6762	129.8	126.7
2.	0.2274	39.5	140.0



tube and stopcock next the globe to a much higher temperature, in order to volatilise the iodine; consequently there was great risk of cracking the stopcock, and this indeed happened several times. The first (trial) series gave results which pointed towards normal density.

In the next series an attempt was made to find the vapour-density as nearly as possible at the saturation-pressure. The vapour-pressure of iodine at  $132^{\circ}$  is 164.6 mm., from the results of Professors Ramsay and Young ('Chem. Soc. Journ.,' vol. 49, 1886, p. 455), and several determinations were made at about this temperature and at about 150 mm. pressure. Constant results were not obtained, although much time and trouble were expended on the experiments. The numbers obtained were:—247.6, 251.2, 204.5, and 184.9. The iodine was allowed to blow out until none could be seen on the bottom of the globe, but it was extremely difficult to decide whether it had all volatilised or not, and no reliance can be placed on the results, notwithstanding the close agreement of the first two numbers with 254 ( $= 2 \times 127$ ). Another plan was then adopted.

*Vapour-density of Iodine from Determinations of the Velocity of Sound by Kundt's Method* ('Poggendorff's Annalen,' vol. 135, 1868, p. 337).

The apparatus is best understood from the diagram (fig. 4). The glass tube CD, about 2 feet long and  $\frac{3}{4}$  inch in diameter, was supported inside a larger tube, GH, by corks, as shown; CD was slightly

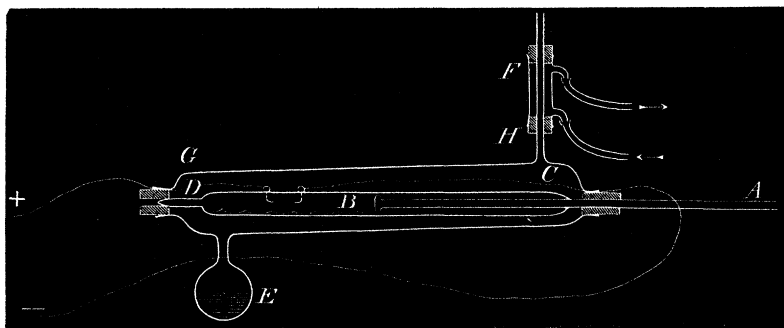


FIG. 4.—Section of Apparatus.

inclined one way, and GH the other. The bulb E contained chlorobenzene; F is a condenser; AB is a small-sized tube sealed into the tube CD at C; it was enlarged at B, so as to fit the tube loosely, but not to touch the walls.

*Method of Procedure.*—Some solid powdered iodine was introduced

into the tube CD, and shaken down to the end C. Some finely-divided precipitated silica was then introduced, and distributed along BD. The air was expelled by heating the tube with a Bunsen's burner, at the same time exhausting it by means of a water-pump; the end D was then sealed off. The tube CD was then placed inside the wide tube GH, as shown in the figure; the chlorobenzene was boiled, and when the whole tube had been heated for a few minutes, the projecting tube AC was rubbed with a cloth moistened with alcohol. The whole tube AB vibrated, the iodine vapour in BD was thrown into vibrations, and the silica on the lower part of the tube formed little heaps at the nodes, and streaks perpendicular to the length of the tube at the loops. The tube was then allowed to cool, withdrawn from the larger tube, and placed on a horizontal millimetre scale (an etched mirror scale was used). It was easier to determine the position of the loops than of the nodes when silica was used. The mean distance between two loops was then calculated. Similar experiments were made with air.

Let  $l_1$  = mean distance between two loops for air.

$l_2$  = " " " iodine vapour.

$d_1$  = density of air.

$d_2$  = " " iodine vapour.

$k_1$  =  $\frac{\text{sp. heat at const. press.}}{\text{sp. heat at const. vol.}}$  for air.

$k_2$  = " " for iodine vapour.

Then it follows from the laws of the propagation of sound that

$$d_2 = \frac{l_1^2}{l_2^2} d_1 \frac{k_2}{k_1}.$$

*Results.*— $l_1$  was found to be (1) 35·4, (2) 35·8, (3) 35·7, eleven readings being taken in each experiment. The mean of (2) and (3) was taken as the correct value of  $l_1$ , these being the most trustworthy experiments. The results obtained for iodine vapour are here tabulated:—

	$l_2$ .	Number of readings.	V.-d.
1.	15·23	11	132·0
2.	14·94	12	137·4
3.	11·68	10	126·3
4.	11·52	10	129·7
5.	11·75	9	124·7

Experiments (1) and (2) are not reliable, as the vibrating glass tube gave a different note from that produced in the experiments on air; it gave one of two notes, according to the way in which it was clamped. The interval between these notes was estimated by ear as a fourth, but it could not be determined accurately owing to the highness of the notes, which appeared also to vary slightly in pitch. The mean of experiments (3), (4), and (5) is 126.9. In the calculation,  $k_1$  was taken as 1.405 (Röntgen), and  $k_2$  as 1.31 (Strecker). These results show conclusively that saturated iodine vapour, and therefore liquid iodine also, are composed of diatomic molecules,  $I_2$ . This result agrees with the late work of Ernst Beckmann ('*Zeitschrift für Physikal. Chem.*,' vol. 5, 1890, p. 76) on the molecular weight of iodine in solution in ether and carbon bisulphide; the numbers varied from 235 to 261 for solutions in ether, and from 263 to 283 for solutions in carbon bisulphide.

A single experiment was performed with bromine in the same manner; the mean distance between the heaps of silica was 12.22 mm. at a temperature of about 29°. Compared with air at the same temperature, this gives a vapour-density 85.05. This points to a normal density, as would be expected. There was considerable uncertainty as to the temperature, because no heaps were formed while the bromine vapour was saturated, and the tube was therefore heated with a Bunsen's burner. Iodine vapour refused to give heaps in the same way when left long enough in contact with liquid iodine to become saturated. It was predicted by Professor Fitzgerald, in a private letter to Professor Ramsay, that sound would not be propagated through saturated vapour, because the rate of propagation of a compression would not be the same as that of an expansion, owing to the difference in elasticity in the two cases. Either the expansion or the compression of a sound-wave would produce condensation in any saturated vapour; in the case of saturated steam, *expansion* causes condensation, except at high temperatures (above the "temperature of inversion"). At present there are not sufficient data to calculate the effect of a wave of compression or expansion upon saturated iodine vapour; but condensation would take place either during a compression or an expansion, and the ratio  $dp/dv$ —and therefore the elasticity,  $v dp/dv$ —would be quite different in the two cases. The sound-waves would interfere with one another, and become confused, so that no sound would be propagated through the vapour.

*Induction Spark through Iodine Vapour.*—An experiment was then made to determine if the passage of the induction spark through iodine vapour effected its dissociation. Professor J. J. Thomson obtained vapour-densities 137 and 130 for unsparked iodine, and 110, 115, 84, and 86 for sparked iodine, the last vapour-density being determined twenty-four hours after sparking. Professor Thomson

says ('Roy. Soc. Proc.,' vol. 42, 1887, p. 344), "The appearance of the dissociated iodine is not greatly different from that of the unsparked; its colour, however, is, I think, a little lighter, and not so uniform. I was not able to detect any change in the absorption-spectrum produced by the sparking. The electric strength of the sparked gas was, however, less than that of the unsparked." The same apparatus was used, platinum wires being fused into the glass (see fig. 4). The jacket used was methyl salicylate vapour, temperature  $223^{\circ}5$ ; the iodine was boiled out at the atmospheric pressure, and the tube then sealed at D. The mean distance between the heaps without sparking was 14.24 mm., and after sparking for fifteen minutes, and cooling for three minutes (to allow the vapour to regain the temperature of the jacket), the mean distance was 14.3 mm. Another experiment was then made, so that the heaps were formed *during* the sparking; the mean distance between the heaps was 14.2 mm. on the side of the piston near the vibrator, and 14.4 mm. on the other side; the difference is probably due to the heating effect of the induction sparks.

The results may be tabulated thus :—

Mean distance between heaps.		
Before sparking.	After sparking.	During sparking.
14.24	14.3	14.2
		14.4

Suppose that complete dissociation of the iodine vapour took place on sparking, then the pressure would be doubled, and therefore the elasticity would be doubled; but the density (taking no account of the pressure) would remain unaltered.

Let  $v_1$  = velocity of sound in the undissociated iodine vapour.

$v_2$  = " " completely dissociated ditto.

$e$  = elasticity of the undissociated vapour.

$d$  = density of the iodine vapour (same in both cases).

Then

$$v_1 = \sqrt{\frac{e}{d}}$$

and

$$v_2 = \sqrt{\frac{2e}{d}}.$$

But the distance between the heaps of silica (half a wave-length) is directly proportional to the velocity of sound in the vapour; therefore, if any dissociation took place, there would be a marked increase in the distance between the heaps on sparking.

The results given above agree within the limits of the errors of

experiment, and it is concluded, therefore, that sparking does not produce any permanent dissociation, although very probably a momentary dissociation is caused near the terminals when a spark passes. The length of the spark in the iodine vapour was about 1 inch; the coil was capable of giving a 3-inch spark in air. By opening the tube under water, it was found to contain about 5 per cent. of air; this would tend to aid dissociation, and would in no way lessen the value of the experiment.

The probable experimental error was about 1 per cent., and was caused by the difficulty in reading the distance between the loops as indicated by the arrangement of the silica.

*Vapour-density of Sulphuric Anhydride.*

The apparatus used to determine the vapour-density of sulphuric anhydride was similar to that used for iodine. The only work that has been done on this subject is apparently that by Schultz-Sellack ('Poggendorff's Annalen,' vol. 139, 1870, p. 480) and Mitscherlich ('Watts's Dictionary'), who both found the vapour-density normal. Some of the trioxide was introduced into a small flask, the neck of which was then sealed on to the tube from the inner globe; it was then sublimed into the globe, which had been previously exhausted, by heating the flask. The vapour-density was then determined in the usual way. The trioxide was absorbed by water, and estimated by means of a standard ammonia solution. Using cochineal as indicator, it was found possible to titrate accurately to one drop of a decinormal solution in the following way:—The relative value of seminormal (approximately) solutions of acid and ammonia was found, and these solutions were then diluted to decinormal strength; a neutral solution was then made by using decinormal acid and ammonia in the proportion found for the seminormal solutions, and this was used as a standard neutral solution, with which the solutions titrated were compared. The chief difficulty was the formation of sulphuric acid above the stopcock; it was partially obviated by introducing a horizontal bulb-tube above the stopcock—this retained most of the acid. Only one series of experiments was made; the first result is very nearly at saturation-pressure.

	Temperature.	Weight of SO <sub>3</sub> .	Pressure.	V.-d.
		grms.	mm.	
1.	22°·1	0·1281	56·7	40·9
2.	22°·7	0·08754	40·5	39·2
3.	22°·8	0·04876	22·1	Calc. normal.

It was useless to estimate the residual amount of trioxide, as sulphuric acid had collected in the lower part of the globe while the trioxide was being sublimed into it. The vapour-density at the lowest pressure was therefore assumed to be normal (corresponding to  $\text{SO}_3$ ), as it would be in all probability, and on this assumption the other vapour-densities are also normal. If the third vapour-density were actually above normal, the second would be less above normal, and the first still less; while, if the third vapour-density were actually below normal, the others would also be below normal; these alternatives are very improbable, and I regard it as fairly proved that the formula of sulphuric anhydride is  $\text{SO}_3$ , and not  $\text{S}_2\text{O}_6$ .

*Vapour-density of Aqueous Hydrochloric Acid.*

Commercial hydrochloric acid was distilled until the boiling point became constant, at  $108\cdot2^\circ$  (pressure, 745 mm.). The distillate was then collected and used for vapour-density determinations; to find the percentage of real acid, weighed quantities were titrated with a standard soda solution. The acid used in Series I contained 20·82 per cent.  $\text{HCl}$ ; that in Series II, 21·33 per cent.; and Series III, 20·45 per cent. The last two samples were distilled from pure acid. The vapour-density was found by means of the apparatus used for iodine. The acid coming over on lowering the pressure was absorbed by a standard soda solution in the absorption-tube; much of it, however, condensed above the stopcock, and caused some difficulty.

Results.

Series.	Temperature.	Capacity of globe.	Weight of $\text{HCl}$ and $\text{H}_2\text{O}$ .	Pressure.	V.-d.	Theoretical V.-d.
		c.c.	grms.	mm.		
I.	$131^\circ\cdot2$	509·2	0·3004	741·8	10·01	10·06
	132·7	649·2	0·3502	773·5	8·81	„
			0·3038	575·1	10·30	„
			0·1495	324·4	8·96	„
			0·06035	126·5	9·28	„
II.	132·2	537·0	0·3204	762·0	9·88	10·09
			0·2349	580·9	9·50	„
			0·1742	428·7	—	„
			0·07778	191·4	9·54	„
III.	131·5	354·9	0·2134	747·8	10·12	10·04
			0·1621	573·8	10·02	„
			0·1027	357·1	10·20	„
			0·04629	146·4	11·22	„

There was some loss in Series I and II in removing the acid from above the stopcock; this was done by aspirating air through the tube, which was heated by a Bunsen's burner, and absorbing the acid in a soda solution; but an acid fume was formed, which refused to be absorbed. In Series III, the apparatus with the jacketed stopcock was used, and the acid which collected above the stopcock was washed out. The vapour-density in the extreme right-hand column is calculated for a mixture of hydrochloric acid and water in the proportions found by titration. These results show that no compound of acid and water is formed, at least at the temperature employed; they confirm the results of Bineau, who found a vapour-density 10.04 at the atmospheric pressure (*'Annales de Chimie,'* vol. 7, 1843, p. 257).

III. "On Barometric Oscillations during Thunderstorms, and on the Brontometer, an Instrument designed to facilitate their Study." By G. J. SYMONS, F.R.S. Received April 24, 1890.

The fact that a rise of the barometer occurs during thunderstorms has been supposed by many to be newly discovered through the general establishment of self-recording barometers; but Dr. Hellmann has shown that it was noticed by J. J. Planer as far back as 1782. In 1784, Rosenthal epitomised the facts as follows:—"When a thunderstorm approaches the place where a barometer is situated, the mercury in the tube begins to rise; the nearer the thunder-cloud comes to the zenith of the observer, the higher does the mercury rise, and it reaches its highest point when the storm is at the least distance from the observer. As soon, however, as the cloud has passed the zenith, or has become more distant from the observer, the weight of the atmosphere begins to decrease and the mercury to fall." A few years later, Toaldo determined the amount of the rise in several storms, and found it to be between 1 and 2 lines (0.09 in. to 0.18 in.).

Professor Strehlke (in 1827-30) made several sets of observations, and found the rise to be from 0.04 in. to 0.06 in., and was probably the first to point out that the highest point of the barometer is not absolutely synchronous with the passage of the centre of the storm-cloud, but seems rather to be always at a certain distance from it.

Kaemtz, in his *'Lehrbuch'* (1832), suggests that the rise is produced by the inrush of air towards the site of the storm, this accumulation causing the rise of the barometer as the storm nears the zenith.

Although Luke Howard had a recording barometer at work in the early part of this century, he seems to have failed to notice the

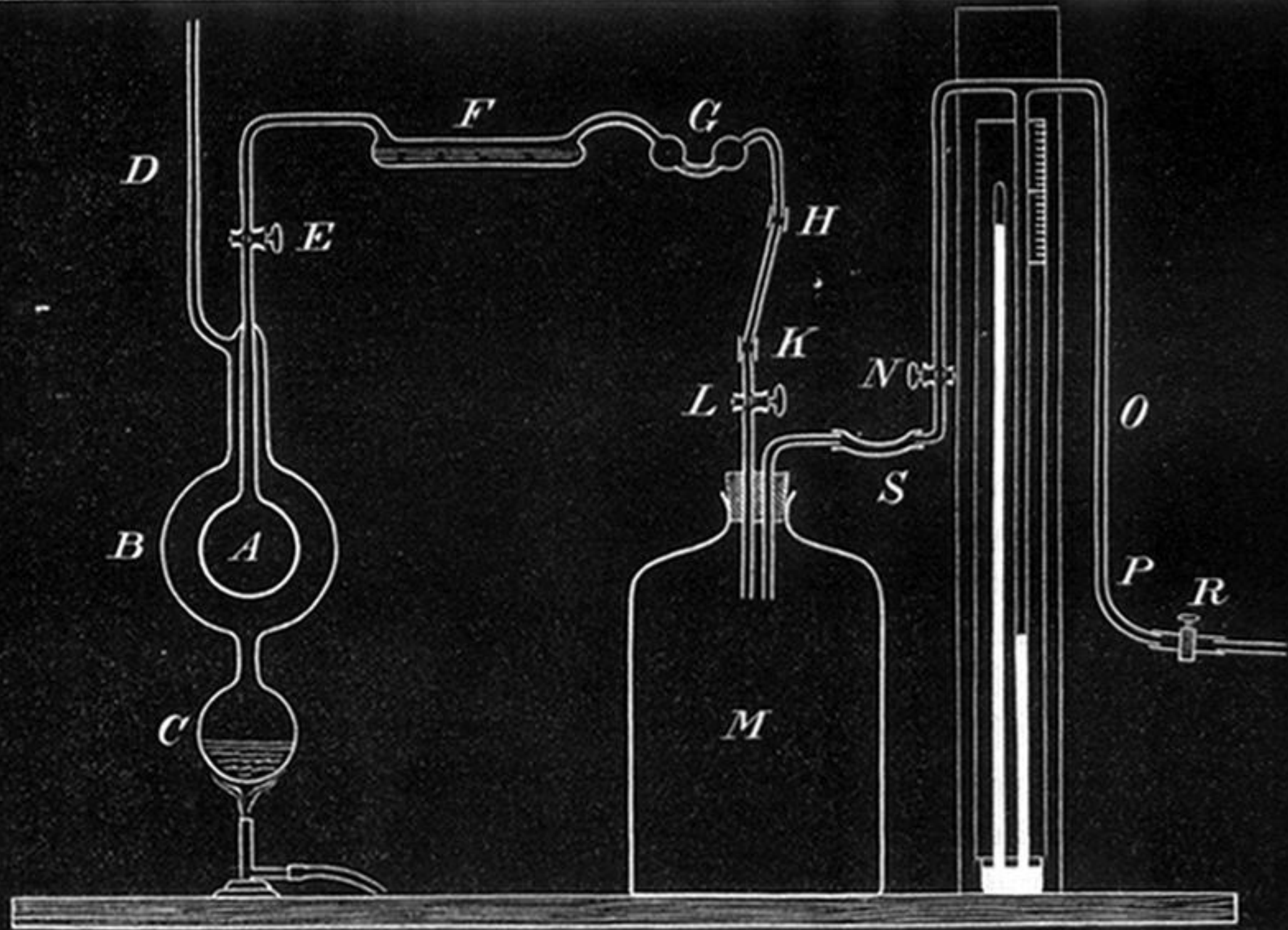


FIG. 1—Apparatus used for determining the Vapour-density of Bromine.  
(Section.)



FIG. 2.

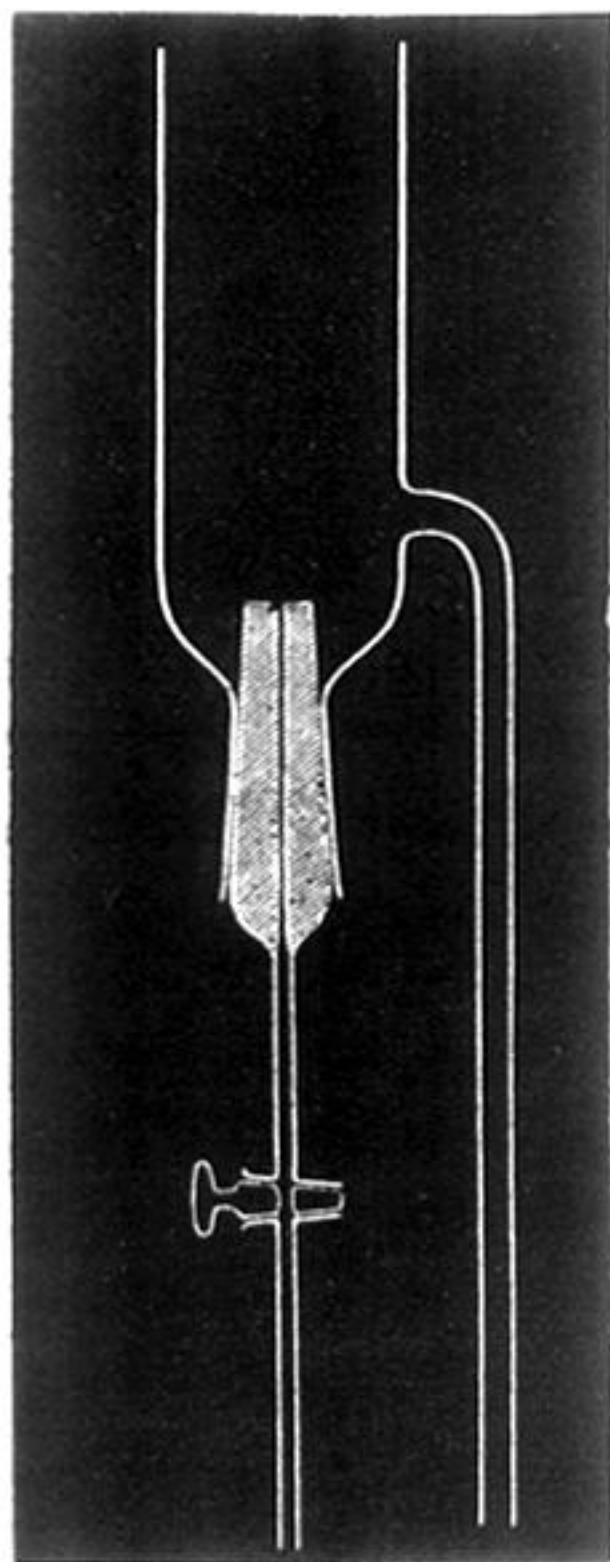
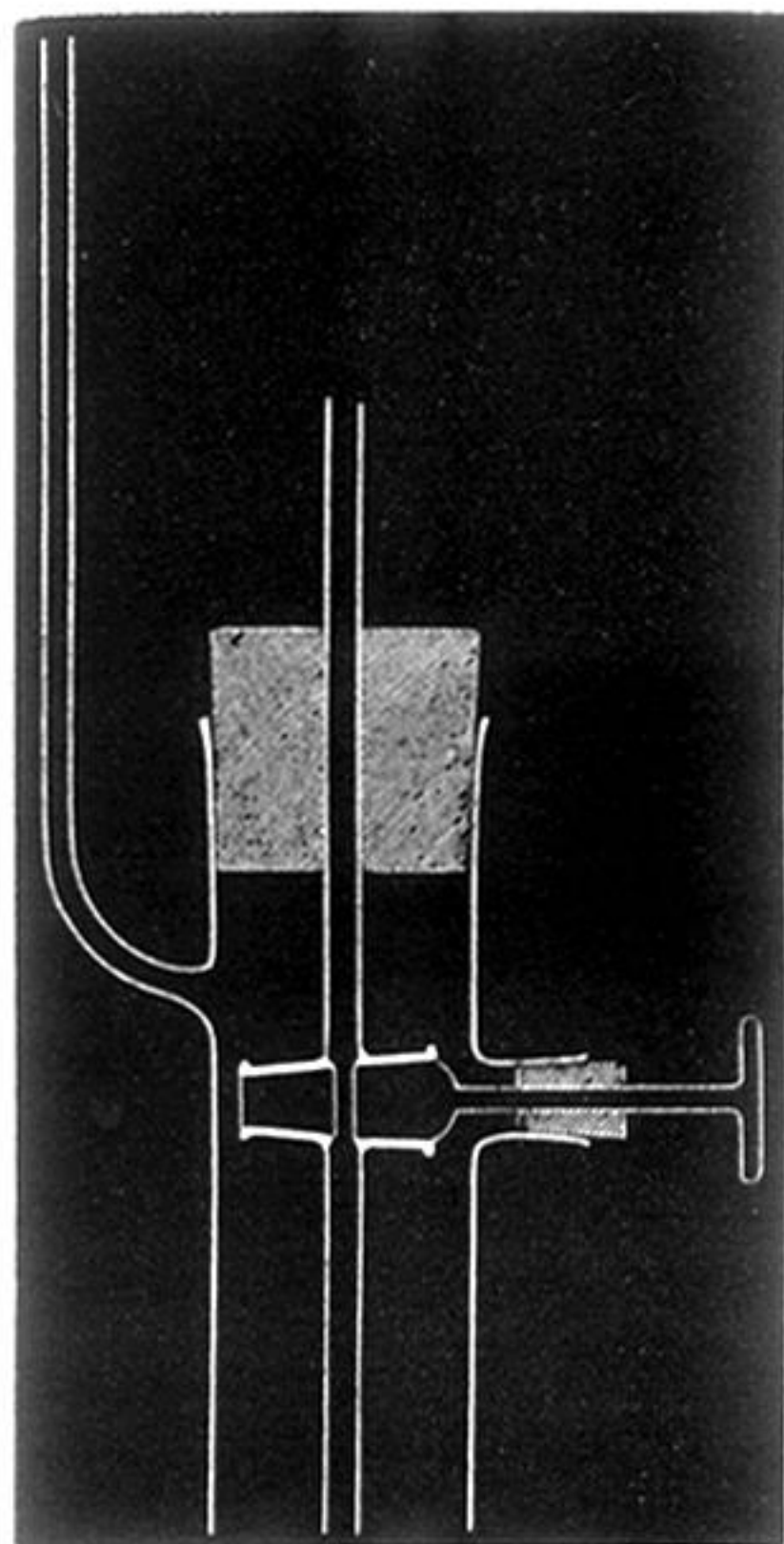


FIG. 3.



Forms of Apparatus used for Iodine and Aqueous Hydrochloric Acid. (Section.)

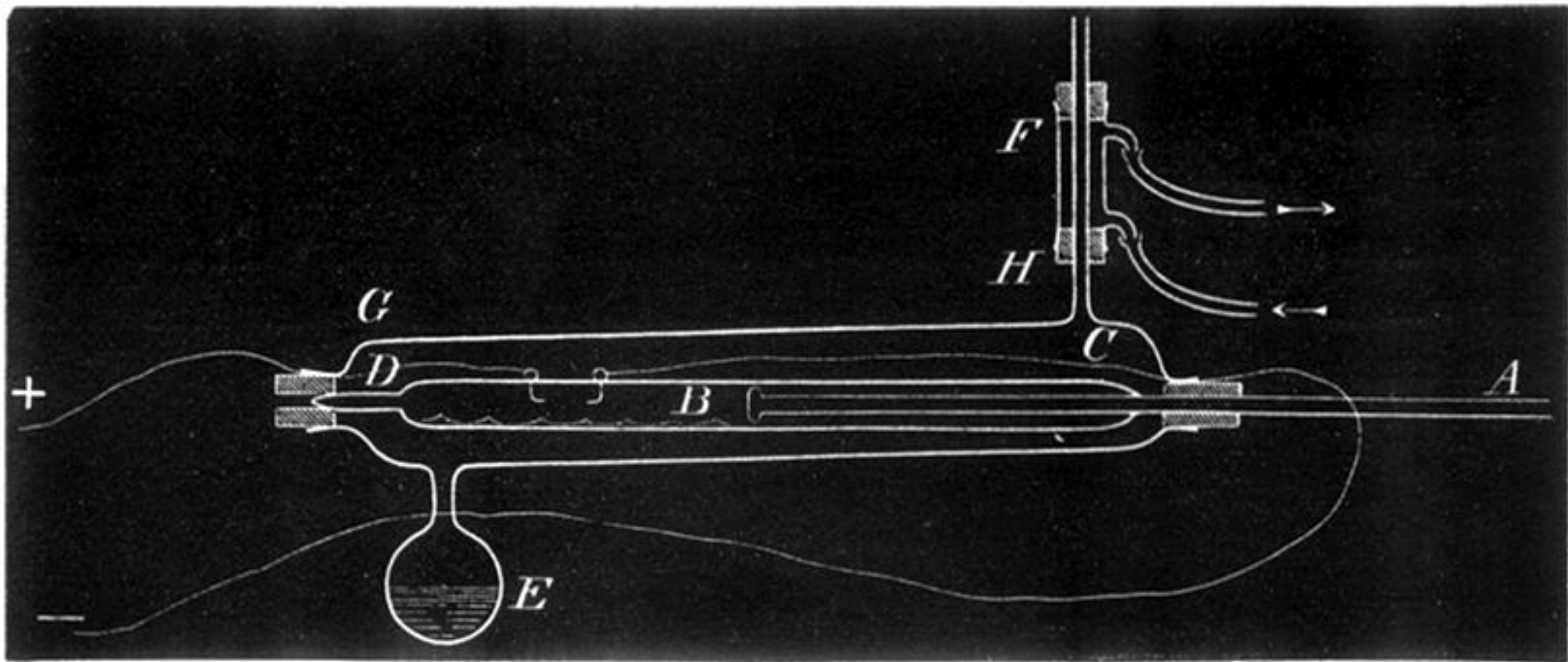


FIG. 4.—Section of Apparatus.